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# Green Policies and Public Finance in a Small Open Economy*

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## Abstract

We explore the effects of greener preferences for the public finances, employment, and the domestic capital stock in a second-best framework. We find that greener preferences typically result in capital flight. Also, employment declines despite the factor substitution that is induced by a lower tax on labour and a higher tax on natural resources. If the uncompensated wage elasticity of labour supply is positive, private utility declines. Public consumption, in contrast, may rise if most of the improvement in environmental quality occurs through a lower level rather than a cleaner composition of economic activity. However, if the labour supply curve bends backwards, private utility rises while public consumption falls.

## I. Introduction

The deterioration of the natural environment constitutes one of the major challenges facing public policy today. Business groups are concerned that environmental protection induces both capital flight and major losses in private income. Environmental groups, in contrast, maintain that a more ambitious environmental policy may not impose large costs. In particular, environmental taxation may be attractive, especially for the high-tax countries of Western and Northern Europe. In these countries, the

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argument goes, the revenues from environmental taxes could be used to cut the high levels of distortionary taxation. In this way, pollution taxation would yield not only a cleaner environment but also a less distortionary tax system. Accordingly, public spending would become easier to finance, allowing for a rise in public spending on important public priorities. Alternatively, the welfare gains associated with a less distortionary tax system could be allowed to boost private rather than public welfare.

As far as the distortionary impact of taxation is concerned, the adverse impact of high levels of labour taxation on labour supply and employment is of particular concern in most European countries. In this connection, some proponents of environmental taxation maintain that moving the tax burden away from the "desirable" activity of employment toward undesirable pollution would provide a welcome boost to employment and thus to the tax base of the public sector. In particular, changing the tax structure away from labour taxation toward environmental taxation would encourage employers to substitute labour for capital and other inputs, thereby making production more labour intensive. At the same time, a lower level of labour taxation would yield higher after-tax wages, thereby increasing the incentives to supply labour.[1]

We explore the interplay between environmental externalities and the optimal level and structure of distortionary taxes and public spending. Following the pioneering work of Sandmo (1975), we investigate these issues in a second-best framework in which taxes serve the dual purpose of generating revenues and internalising environmental externalities. In contrast to most of the literature on optimal taxation, we do not just characterise the first-order conditions but also develop a general equilibrium model to explore how various shocks affect optimal decisions on taxes, public spending, and environmental policy. Besides the consequences for the public finances, and macroeconomic implications for employment and international capital flows are also analysed.

A similar framework was adopted to examine environmental policy in a closed economy with consumption externalities; see Bovenberg and van der Ploeg (1994). There it was found that a more ambitious environmental policy associated with increased environmental concern typically reduces employment. However, only pollution in consumption was considered and it was assumed that labour is the only input into production and labour productivity is fixed. In the present paper we analyse pollution in production rather than consumption. Moreover, we allow for substitution in

[1] Our competitive model of the labour market does not allow for involuntary unemployment. However, from an efficiency point of view, the levels of employment and labour supply are too low due to distortionary taxes on labour.

production between labour, capital, and a third input, natural resources, which damages the environment when used in production. Within this framework, a more ambitious environmental policy may induce substitution away from resources towards labour, thereby making production more labour intensive. A second major difference between the two papers is that here we consider a small open economy instead of a closed economy. Opening up the economy seems relevant for most European countries and allows us to investigate the issue of capital flight.

Section II presents the model of a small open economy which uses capital, labour and natural resources to produce a traded consumption good. Welfare is an increasing function of private consumption of produced commodities and leisure, public consumption of produced goods, and environmental quality. Environmental quality worsens on account of pollution arising from the use of natural resources in production, but can be improved by public spending on abatement. Section III uses this framework to find the first-order conditions characterising the optimal levels of public consumption and abatement and derives expressions for the marginal cost of public funds as well as for the optimal tax rates on labour and the use of natural resources. Section IV derives the comparative statics of private behaviour and optimal policies with respect to various shocks. Section V discusses the consequences of an increase in environmental concern, paying particular attention to the impact on optimal environmental and tax policy, and public consumption as well as the macroeconomic implications for employment and capital flight. Section VI allows for a direct positive effect of environmental quality on production.

## II. Natural Resources, Employment and Capital in a Small Open Economy

In this section, we specify various budget constraints in our small open economy, the behaviour of firms and households, market equilibrium and ecological relationships.

*Budget Constraints*

We focus on a small open economy which can freely trade goods, capital and natural resources (e.g., oil or natural gas) on competitive world markets. Labour, however, is immobile internationally. National income amounts to the income received by domestic residents and must equal domestic demand for goods by domestic households and the domestic government:

$$Q \equiv F(K, NL, R) + P_R^*(R_E - R) + P_K^*(K_E - K) = NC + G + A, \quad (1)$$

where $Q$, $K$, $K_E$, $P_K^*$, $L$, $R$, $R_E$, $P_R^*$, $C$, $G$, $A$ and $N$ denote, respectively, national income, capital used in domestic production, the domestic endowment of capital, the world rental price of capital, hours worked by each household, the use of natural resources in domestic production,[2] the sale of the (exogenous) endowment of domestically owned natural resources, the world price of natural resources, consumption of goods by the representative household, public consumption, public abatement, and the number of households, $F(\cdot)$ is concave and stands for a neoclassical production function with constant returns to scale. An alternative way of expressing equation (1) is that net exports of goods (i.e., the trade balance of goods) must equal net imports of natural resources and capital:

$$F(K, NL, R) - NC - G - A = P_R^*(R - R_E) + P_K^*(K - K_E). \tag{1'}$$

Profits of firms ($\pi$) are defined as sales minus the costs of labour, natural resources and capital — including taxes on labour and natural resources:

$$\pi \equiv F(K, NL, R) - (w + t_L)NL - (P_R^* + t_R)R - P_K^* K \tag{2}$$

where $w$, $t_L$, and $t_R$ denote the market wage, the (employers') tax rate on labour and the tax rate on the use of natural resources, respectively. The household budget that can be used for consumption of goods consists of wage and profit income, lump-sum subsidies received from the government and the return on the endowments of capital and natural resources:[3]

$$C = wL + (1/N)[\pi + P_K^* K_E + (1 - \xi) P_R^* R_E] + T \tag{3}$$

where $(1 - \xi)$ represents the share of the national endowment of natural resources that is owned by private agents and $T$ stands for the (per-capita) lump-sum transfers received by each household from the government. Note that $\xi$ may, alternatively, be interpreted as a tax rate on the return on the ownership of natural resources. Equation (3) assumes that each household owns an equal share of private assets. Spending of the government on public consumption, public abatement and lump-sum transfers must be financed by taxes on labour and the use of natural resources and by income from the sale of natural resources owned by the government:

$$G + A + NT = t_L NL + t_R R + \xi P_R^* R_E \tag{4}$$

where $\xi$ denotes the share of the endowment of natural resources that is owned (or taxed) by the government. According to Walras' law, (4) follows from (1), (2) and (3).

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[2] Natural resources ($R$) and capital ($K$) may also be interpreted as dirty and clean capital, respectively. We are indebted to Pierre Pestieau for this interpretation.

[3] We assume that the government cannot impose a residence-based tax on the capital endowment ($K_E$), because it cannot monitor foreign-source income.

*Factor Demand by Firms*

Firms maximize profits under perfect competition and thus equalise the marginal product of each factor to its user cost:

$$F_K(K/NL, 1, R/NL) = P_K^*, \quad F_R(K/NL, 1, R/NL) = P_R^* + t_R,$$
$$F_{NL}(K/NL, 1, R/NL) = w + t_L \tag{5}$$

where subscripts denote partial derivatives. The first two first-order conditions yield the demand for capital and natural resources conditional on the level of employment:

$$K/NL = k(P_K^*, P_R^* + t_R), \qquad R/NL = r(P_K^*, P_R^* + t_R). \tag{6}$$

Note that $k_K = F_{RR}/\Delta < 0$, $k_R = r_K = -F_{RK}/\Delta$ and $r_R = F_{KK}/\Delta < 0$, where partial derivatives of $k(\cdot)$ and $r(\cdot)$ with respect to $P_K^*$ and $P_R^* + t_R$ are denoted by the subscripts $K$ and $R$, respectively. Concavity of the production function implies that $\Delta \equiv F_{RR}F_{KK} - F_{RK}^2 > 0$. Factor substitution away from capital (natural resources) towards labour takes place if the user cost of capital (natural resources) rises. If capital and natural resources are cooperant factors ($F_{RK} > 0$), an increase in the cost of natural resources (capital) induces substitution away from capital (natural resources) towards labour. Substitution of the relative factor demand functions (6) into the third first-order condition given in (5) yields the factor price frontier:

$$w + t_L = \phi(P_K^*, P_R^* + t_R). \tag{7}$$

Constant returns to scale implies that $\phi_K = (F_{NL,K}F_{RR} - F_{RK}F_{NL,R})/\Delta = -k$ and $\phi_R = (F_{KK}F_{NL,R} - F_{NL,K}F_{KR})/\Delta = -r$ where the partial derivatives of $\phi(\cdot)$ are denoted by the subscripts $K$ and $R$. The producer wage is a negative function of both the producer cost of natural resources and the user cost of capital. Since the user cost of capital and the price of natural resources are determined on global competitive markets, a given tax on natural resources ($t_R$) uniquely determines the producer wage ($w + t_L$). Constant returns to scale implies that profits ($\pi$) are zero in equilibrium.

*The Representative Household*

Preferences are weakly separable in private utility (the bundle of private consumption and leisure), public consumption and environmental quality. The utility function of the representative household can thus be written as $U[M(C, V), G, E]$, where $U[\cdot]$ stands for total utility, $M(\cdot)$ represents private utility, $V$ is leisure (i.e., $1 - L$ as the endowment of time is normalised as unity), and $E$ denotes environmental quality. Households are atomistic and take the level of public consumption and environmental quality as given. They choose leisure and private consumption to maximise (private) utility subject to the budget constraint (3). Households thus equate the marginal rate of substitution between private consumption and leisure to the market (consumption) wage, i.e., $M_V/M_C=w$. This yields the demand for goods, the demand for leisure, indirect private utility and indirect social utility:

$$C=c(w,Y),\qquad V=v(w,Y),\qquad M=m(w,Y),$$
$$U[m(w,Y),G,E]\equiv u(w,Y,G,E) \tag{8}$$

where private non-labor income ($Y$) is given by

$$Y\equiv N^{-1}[P_K^*K_E+(1-\xi)P_R^*R_E]+T. \tag{9}$$

The (uncompensated) wage elasticity of labour supply is defined as $\varepsilon_L\equiv -wv_w/L$. Roy's identity gives employment as $L=u_w/\lambda$ where $\lambda\equiv U_C=U_M M_C=u_Y$ is the marginal utility of private income.

*Labour Market Equilibrium*

There is no international migration of labour. Hence, equilibrium on the labour market requires that the domestic demand for labour from (6) must equal the domestic supply of labour from (8):

$$NL=K/k[P_K^*,P_R^*+t_R]=\mathrm{N}[1-v(w,Y)]. \tag{10}$$

Substitution of the factor price frontier (7) into (10) yields an expression for the equilibrium level of domestically employed capital as a function of the producer costs of natural resources and capital, the tax on labour, and the level of non-labour income:

$$K=N[1-v(\phi(P_K^*,P_R^*+t_R)-t_L,Y)]\,k(P_K^*,P_R^*+t_R). \tag{11}$$

A higher tax on labour reduces the consumption wage. If labour supply slopes upwards, a lower wage rate decreases both employment and domestically employed capital. A higher level of non-labour income raises the demand for leisure ($v_Y>0$), thereby reducing employment and capital. A higher user cost of natural resources depresses the market wage. If capital and natural resources are cooperant, the resulting change in relative input prices causes the demand for capital to decline relative to labour demand. If the labour supply curve slopes upwards, the lower wage reduces labour supply. As both employment and the capital–labour ratio decline, capital employed in domestic production falls. A higher cost of capital lowers the wage and, if labour supply slopes upwards, lowers labour supply. It also induces substitution away from capital towards labour. Accordingly, domestically employed capital falls.

*Environmental Quality*

Environmental quality worsens when more natural resources are used and less public abatement is undertaken:

$$E \equiv e(A) - R, \quad e' > 0, \quad e'' < 0, \tag{12}$$

where $e(\cdot)$ denotes the effectiveness of public abatement.[4]

## III. Environmental Quality and Optimal Government Policy

We now derive optimal government policy. The government selects the level of public consumption ($G$) and public abatement ($A$), the tax on labour ($t_L$), the tax on the use of natural resources ($t_R$), and the level of transfers ($T$) to maximise social welfare, i.e., $Nu[w, Y, G, E]$, subject to the factor price frontier (7), the definition of non-labour income (9), the ecological relationship (12), the demand for natural resources (6) (in which $L = 1 - v[\phi(\cdot) - t_L, \ Y]$ has been substituted), capital employed domestically (11), and the government budget constraint (4). The government is thus able to attain the first-best outcome in a competitive, market economy. This may be seen from the first-order condition for the level of lump-sum transfers:

$$Nu_Y - N\mu = 0 \tag{13}$$

where $\mu$ stands for the marginal reduction in social welfare arising from raising one more unit of public funds. The marginal cost of public funds (MCPF), $\eta \equiv \mu/\lambda$, expresses this fall in welfare in money units. Expression (13) reveals that if lump-sum subsidies and taxes are available, the shadow price of public funds ($\mu$) equals marginal private utility of income ($u_Y = \lambda$). Hence, the MCPF (i.e., $\eta$) is unity. In addition, the sum of the marginal rates of substitution between public and private consumption goods reduces to the marginal rate of transformation (see (14) below). The first-best outcome can thus be attained in a competitive market economy.

In the remainder of the paper, however, it is assumed that lump-sum subsidies and taxes are not available (i.e., $T = 0$). Accordingly, the government has to use distortionary taxes (or subsidies) to finance public

[4] Alternatively, we can explicitly allow for cross-border pollution by writing (12) as

$$E = e(A) - \beta_1 R - \beta_2(R_E - R) = e(A) - (\beta_1 - \beta_2)R - \beta_2 R_E$$

where $\beta_1$ and $\beta_2$ are the environmental damages imposed at home by one unit of resources used domestically and abroad, respectively. As long as $\beta_1 > \beta_2$ and units of measurement are chosen appropriately, this is equivalent to (12).

spending. The resulting second-best allocation yields, of course, lower social welfare than the first-best outcome.

*Public Consumption and Abatement*

Maximisation of social welfare with respect to the level of public consumption requires that the sum of the marginal rates of substitution between public consumption and private consumption be equal to the MCPF:

$$NU_G/U_M M_C = \eta \equiv \mu/\lambda. \tag{14}$$

This is the Samuelson rule for the optimal provision of public goods modified for the absence of lump-sum taxation. If the MCPF exceeds unity ($\eta > 1$) due to the deadweight loss of distortionary taxation, the sum of the marginal rates of substitution between public and private consumption needs to exceed the marginal rate of transformation (i.e., unity).

The optimal level of public abatement follows from setting the marginal rate of substitution between public consumption and environmental quality equal to the marginal rate of transformation between public abatement and environmental quality ($e'$):

$$U_G/U_E = e'(A) \tag{15}$$

where $e'(A)$ stands for the improvement in environmental quality that can be obtained by one additional unit of public abatement. Unlike (14), (15) does not feature the MCPF because both public consumption and public abatement are financed by distortionary taxation. Hence, the MCPF affects the optimal demands for both these types of public spending in similar ways.

*The Marginal Cost of Public Funds and the Tax on the Use of Natural Resources*

The first-order condition for the optimal tax on the use of natural resources is:

$$[Nu_w + NU_E(R/L)v_w - \mu\{Nt_L + t_R(R/L)\}v_w]\phi_R + \mu R + (\mu t_R - NU_E)r_R NL = 0. \tag{16}$$

The first-order condition for the optimal tax on labour amounts to:

$$-Nu_w - NU_E(R/L)v_w + \mu[N(L + t_L v_w) + t_R(R/L)v_w] = 0. \tag{17}$$

Upon substitution of (17) into (16), we obtain

$$\mu NL\phi_R + \mu R + (\mu t_R - NU_E)r_R NL = 0. \tag{16'}$$

If we make use of $\phi_R = -r$, the expression for the optimal tax on natural resources becomes:

$$t_R \equiv (NU_E/U_M M_C)(1/\eta). \tag{18}$$

Substitution of (14) into (18) yields:

$$t_R = U_E/U_G > 0. \tag{18'}$$

Substituting (18′) into (15), we find for the marginal productivity of abatement:

$$e'(A) = 1/t_R. \tag{15'}$$

Public abatement thus increases with the tax on natural resources.[5]

The optimal tax on the use of natural resources is zero if environmental externalities are absent (i.e., $U_E = 0$). The reason is that a small open economy cannot affect the world market price of natural resources. Hence, the resource tax is fully born by the internationally immobile factor of production, i.e., labour, and thus amounts to an *implicit* labour tax. From a revenue-rasing point of view, the *explicit* labour tax is a more efficient levy on labour income; while both taxes distort labour supply by reducing the consumption wage, only the input tax on resources ($t_R$) distorts production decisions.[6]

Applying Roy's identity ($u_w = \lambda L$) to (17), substituting (18) and dividing by $N\lambda L$ yields the following expression for the MCPF:

$$\eta \equiv \frac{\mu}{\lambda} = \left[\frac{1}{1-\left(\frac{t_L}{w}\right)\varepsilon_L}\right]. \tag{19}$$

If labour supply is inelastic ($\varepsilon_L = 0$), additional labour taxes do not affect the base of the labour tax and thus the MCPF is unity. If labour supply slopes upwards ($\varepsilon_L > 0$), equation (19) reveals that a positive tax on labour raises the MCPF above unity. The reason is that a higher labour tax depresses labour supply, thereby eroding the base of the distortionary labour tax. If, however, labour supply bends backwards ($\varepsilon_L < 0$), the negative income effect associated with a higher tax on labour boosts labour

[5] The same first-order condition would hold if $A$ were private abatement. In that case the pollution tax ($t_R$) would have to be levied on the unabated environmental damage (i.e., $R - e(A)$) rather than on the use of natural resources.

[6] This is, in fact, an application of the well-known Diamond–Mirrlees (1971) result that production efficiency should be maintained in the second-best world. Production efficiency requires that the source-based tax on capital income should be zero.

supply, thereby broadening the labour tax base. This causes the MCPF to fall below unity.

The textbook Pigovian tax rate on the use of natural resources amounts to the sum of the marginal damages of environmental pollution expressed in money units rather than utility units, i.e., $NU_E/U_C > 0$. This is the appropriate optimal tax rate on natural resources if the MCPF is unity, indicating that public funds are not scarcer than private funds (e.g., since lump-sum taxes and subsidies are available or labour supply is perfectly inelastic). However, in a second-best situation in which the government cannot rely on lump-sum instruments and labour supply is elastic, equation (18) shows that the optimal tax rate on the use of natural resources differs from the Pigovian tax rate. In particular, if labour supply slopes upwards, the MCPF is above unity and the optimal tax is lower than the Pigovian tax, which measures the social damage due to the use of resources. The scarcer are public funds, the higher is the MCPF and *ceteris paribus* the smaller becomes the optimal tax on natural resources. The reason is that the optimal resource tax equates the social cost of environmental damage due to resource use to the social benefits of additional tax revenue on account of the resource use. Hence, each unit of used resources does not have to yield as much tax revenue if tax revenue becomes more expensive as indicated by a higher MCPF. Intuitively, the government uses the tax system to simultaneously accomplish two objectives: first, raising public revenues and, second, internalising externalities. If public revenues become scarcer, as indicated by a higher MCPF, the tax system needs to focus more on raising revenue and less on environmental objectives. In this way, a high MCPF cuts the demand not only for public consumption but also for the public good of the environment.

## IV. Comparative Statics

This section goes beyond the first-order conditions of optimal policy provided in the preceding section by exploring the comparative statics of the optimal tax equilibria. Loglinear deviations are denoted by a tilde, unless indicated otherwise. To obtain analytical results, we assume perfect substitution in social utility between private utility, public consumption and environmental quality. Hence, $U_M$, $U_G$, and $U_E$ are proportional to each other and, without loss of generality, constants. Furthermore, the subutility function $M(\cdot)$ is homothetic, so that Engel curves are linear. The first four subsections loglinearise the equations describing, respectively, the behaviour of households and firms, the government budget constraint, and optimal environmental policy. We then turn to the trade-offs between the three components of social welfare (viz. private utility, public consumption, and environmental quality) that follow from the resource constraints. After discussing the optimal demand for private utility and the MCPF, the model is solved in the last subsection.

*Household Behaviour*

Loglinearisation of the household budget constraint (3) yields:

$$\tilde{C}=\beta_L(\tilde{w}+\tilde{L}), \qquad \beta_L\equiv wL/C>0 \tag{3'}$$

where $\beta_L$ stands for the share of labour income in total household income. The first-order conditions give $\sigma_M^{-1}(\tilde{C}-\tilde{V})=\tilde{w}$, where $\sigma_M$ denotes the elasticity of substitution between $C$ and $V$ in private utility $M(\cdot)$. Together with the equilibrium condition $V\tilde{V}+L\tilde{L}=0$, we obtain the changes in private consumption, leisure, labour supply and private utility:

$$\tilde{C}=\beta_L(1+\varepsilon_L)\tilde{w}, \qquad \tilde{V}=-(L/V)\varepsilon_L\tilde{w}, \qquad \tilde{L}=\varepsilon_L\tilde{w},$$

$$\tilde{M}=(1-\alpha_V)\beta_L\tilde{w} \tag{8''}$$

where $\alpha_V\equiv wV(C+wV)^{-1}=V\beta_L(L+V\beta_L)^{-1}$ stands for the share of leisure in private utility and $\varepsilon_L\equiv V(\sigma_M-\beta_L)(L+V\beta_L)^{-1}$ is the (uncompensated) wage elasticity of labour supply. Hence, the labour supply slopes upwards (bends backwards) if the elasticity of substitution between leisure and private consumption goods in private utility $(\sigma_M)$ is greater (less) than the share of labour income in total household income $(\beta_L)$. In that case, the substitution effect dominates (is dominated by) the income effect. In general, the wage elasticity of labour supply rises with the ratio of non-labour to labour income. Private utility rises but the marginal private utility of money income falls with the consumption wage $(w)$:

$$\tilde{\lambda}=\tilde{M}_C=(\alpha_V/\sigma_M)(\tilde{V}-\tilde{C})=-\alpha_V\tilde{w}=-\alpha_V[(1-\alpha_V)\beta_L]^{-1}\tilde{M}. \tag{20}$$

*Factor Demand*

The change in the demand for natural resources can (by using (6)) be written as:

$$\tilde{R}=\tilde{L}-\varepsilon_R\tilde{t}_R, \qquad \varepsilon_R\equiv-F_{KK}(r\Delta)^{-1}(P_R^*+t_R)>0 \tag{6''}$$

where $\tilde{t}_R\equiv dt_R/(P_R^*+t_R)$. The factor price frontier (7) yields:

$$\tilde{w}=-\delta_R\tilde{t}_R-\tilde{t}_L, \qquad \delta_R\equiv(P_R^*+t_R)r/w>0 \tag{7''}$$

where $\tilde{t}_L\equiv dt_L/w$. The consumption wage $(w)$ thus declines if firms face a higher cost of natural resources or a higher tax on labour.

*Market Equilibrium and the Government Budget*

Loglinearising the national income identity (1) or (1′), we arrive at:

$$\alpha_L \tilde{L} + \alpha_R \theta_R \tilde{R} = \omega_C \tilde{C} + \omega_G \tilde{G} + \omega_A \tilde{A} \tag{1''}$$

where the national income shares of labour, the domestic use of natural resources, private consumption, public consumption, and public abatement are defined as $\alpha_L \equiv (w + t_L) NL/Q$, $\alpha_R \equiv (P_R^* + t_R) R/Q$, $\omega_C \equiv NC/Q$, $\omega_G \equiv G/Q$ and $\omega_A \equiv A/Q$, respectively, and $\theta_R \equiv t_R / (P_R^* + t_R)$. Substituting (6″), (7″), and (8″) into (1″) and using $\beta_L \omega_C = (1 - \theta_L) \alpha_L$, where $\theta_L \equiv t_L (w + t_L)^{-1}$, gives

$$\omega_G \tilde{G} + \omega_A \tilde{A} = \Delta^* (\tilde{t}_L + \delta_R \tilde{t}_R) - \alpha_R \theta_R \varepsilon_R \tilde{t}_R,$$
$$\Delta^* \equiv (1 - \theta_L) \alpha_L - \varepsilon_L (\alpha_L \theta_L + \alpha_R \theta_R). \tag{21}$$

By Walras's law, equation (21) also corresponds to the loglinearisation of the government budget constraint (4). Public spending is financed by both an implicit labour tax, i.e., the tax on the use of natural resources, and an explicit tax on labour. The first term in $\Delta^*$ captures the tax *rate* effect (i.e., the revenue effect *ceteris paribus* the tax base), while the second term in $\Delta^*$ stands for the tax *base* effect (i.e., the revenue implications of a change in employment, which constitutes the base of both the implicit and the explicit labour tax). A higher explicit or implicit tax rate on labour reduces the consumption wage and, if the labour supply curve slopes upwards (bends backwards), reduces (raises) labour supply (witness the term $\Delta^*$). Hence, tax revenues rise less (more) than proportionally. Compared to a higher explicit labour tax (i.e., $\tilde{t}_L > 0$), a higher resource tax (i.e., $\tilde{t}_E > 0$) produces an additional adverse effect on tax revenues; by encouraging producers to substitute away from natural resources, the base of the pollution tax is eroded (captured by the term $-\alpha_R \theta_R \varepsilon_R$). This additional substitution effect explains why a tax on natural resources is less efficient in raising public revenue than a tax on labour. To rule out a downward-sloping Laffer-curve for the labour tax, we assume that $\Delta^* > 0$.

*Tax on Natural Resources and Public Abatement*

Loglinearisation of (18′) yields the change in the tax on the use of natural resources:[7]

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[7] A CES sub-utility function for collective goods, say $H \equiv (\gamma_G G^{\xi} + \gamma_E E^{\xi})^{1/\xi}$, $\xi < 1$, gives

$$\tilde{t}_R = \theta_R \{[1 + \gamma'_E (\sigma_S - 1)^{-1}] \tilde{\gamma}_E - [1 + \gamma'_G (\sigma_S - 1)^{-1}] \tilde{\gamma}_G + \sigma_S^{-1} (\tilde{G} - \tilde{E})\}$$

where $\sigma_S \equiv (1 - \xi)^{-1} > 0$ stands for the elasticity of substitution between public consumption and environmental quality, $\gamma'_G \equiv GH_G/H = \gamma_G [\gamma_G + \gamma_E (E/G)^{\xi}]^{-1}$ and $\gamma'_E = 1 - \gamma'_G$. A higher level of public consumption relative to environmental quality induces the government to shift attention to environmental policy and impose a higher resource tax, particularly if $\sigma_S$ is low. We assume in this paper, however, $\sigma_S \to \infty$ and thus that (18″) holds.

$$\tilde{t}_R = \theta_R \tilde{U}_E. \tag{18''}$$

Loglinearising (15′) and then substituting (18″), we find for the change in public abatement:

$$\tilde{A} = (\tilde{t}_R/\theta_R)/\sigma_A = \tilde{U}_E/\sigma_A, \qquad \sigma_A \equiv -Ae''/e' > 0. \tag{15''}$$

A higher utility weight for environmental quality encourages the government to undertake more abatement, particularly if the elasticity of the productivity of public abatement ($\sigma_A$) is low. Intuitively, a higher priority for the environment makes the output of public abatement (i.e., a cleaner environment) more valuable.

*Public Consumption, Environmental Quality and Private Utility*

By substituting (15″), (7″), and (18″) into the government budget constraint (21), we solve for public consumption in terms of the consumption wage. Using (8″) to express $\tilde{w}$ in terms of $\tilde{M}$ gives the change in public consumption in terms of the change in private utility:

$$\omega_G \tilde{G} = -\Delta^*[(1-\alpha_V)\beta_L]^{-1}\tilde{M} - (\omega_A \sigma_A^{-1} + \alpha_R \theta_R \varepsilon_R)\theta_R \tilde{U}_E. \tag{22}$$

Loglinearisation of (12) and making use of (15′) yields:

$$\alpha_E \tilde{E} = \omega_A \tilde{A} - \theta_R \alpha_R \tilde{R}, \tag{12'}$$

where $\alpha_E \equiv t_R E/Q$ stands for the value of the environment as a fraction of national income. Substituting (6″) into (12′) yields:

$$\alpha_E \tilde{E} = \omega_A \tilde{A} - \theta_R \alpha_R \tilde{L} + \theta_R \alpha_R \varepsilon_R \tilde{t}_R. \tag{12''}$$

Hence, environmental quality improves through more abatement, a higher cost of natural resources and a lower level of employment. Substituting (8″), (15″), and (18″) into (12″), we can write the change in environmental quality in terms of the change in private utility and exogenous shocks:

$$\alpha_E \tilde{E} = -\theta_R \alpha_R \varepsilon_L [(1-\alpha_V)\beta_L]^{-1}\tilde{M} + (\omega_A \sigma_A^{-1} + \alpha_R \theta_A^2 \varepsilon_R)\tilde{U}_E. \tag{23}$$

Expressions (22) and (23) summarise the trade-offs between the three components of social welfare (*viz.* private utility, environmental quality and public consumption) that follow from the resource constraints facing the small open economy. In particular, a higher level of private utility (corresponding to lower tax rates and a higher consumption wage) reduces public consumption (see (22)) and, if the labour curve slopes upwards (downwards), worsens (improves) environmental quality (see (23)). A higher priority to environmental quality raises the level of public abatement and, for a given level of private utility, crowds out public consumption and boosts environmental quality.

### *The Demand for Private Utility (Modified Samuelson Rule)*

In order to analyse the optimal trade-off between the three components of social utility, we loglinearise (14) and substitute (20):

$$[\beta_L(1-\alpha_V)]^{-1}\tilde{M}=\alpha_V^{-1}\tilde{\eta}. \tag{24}$$

Relationship (24) can be viewed as the "demand" curve for private utility (see Figure 1). According to the modified Samuelson rule (14), a higher MCPF requires marginal utility of public consumption to rise relative to marginal utility of private consumption. Since marginal utility of public consumption is fixed, marginal utility of private consumption must decline. This requires a rise in the level of private welfare. Hence, the demand curve for private utility slopes upwards.

### *The Marginal Cost of Public Funds*

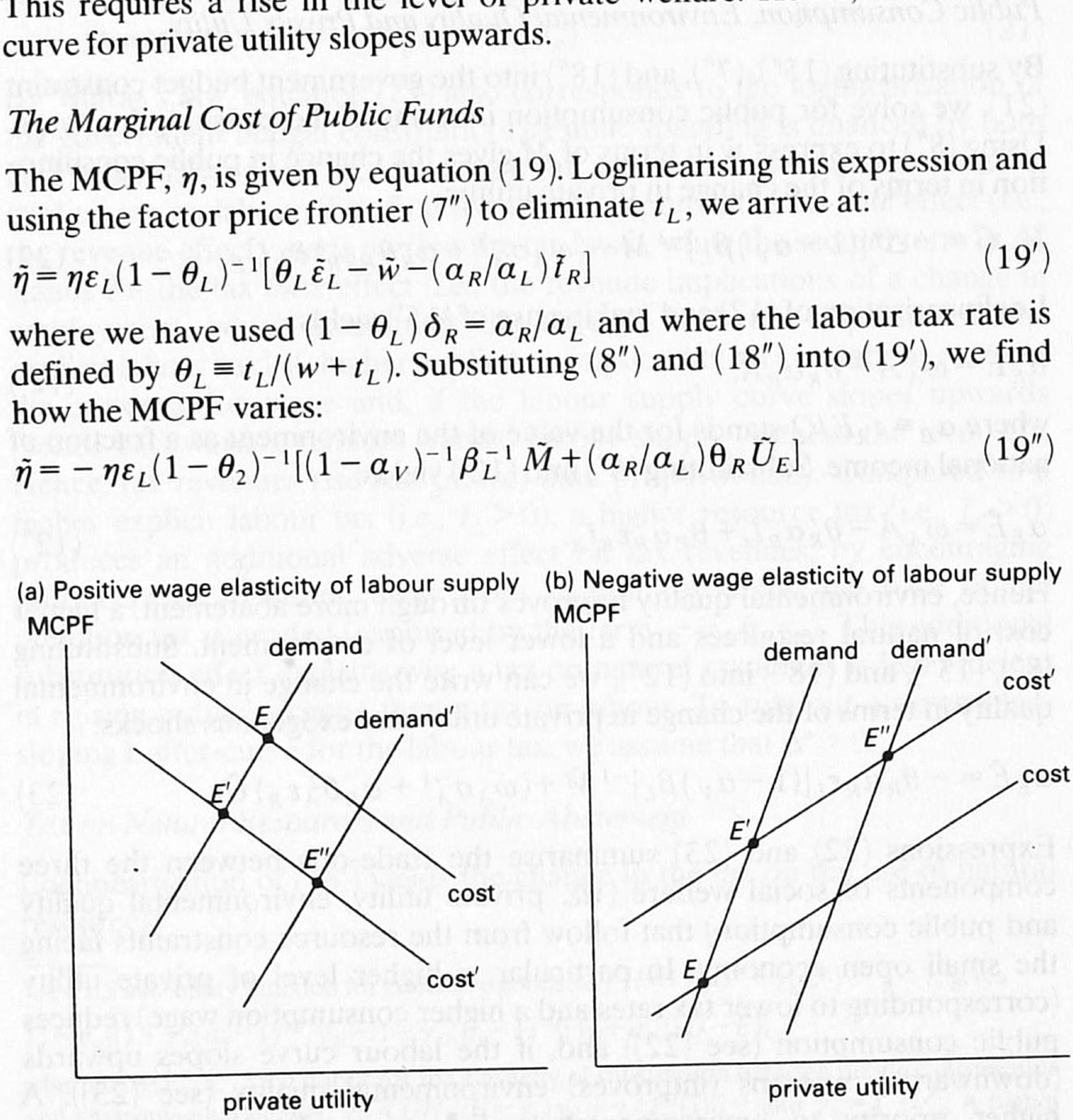
The MCPF, $\eta$, is given by equation (19). Loglinearising this expression and using the factor price frontier (7″) to eliminate $t_L$, we arrive at:

$$\tilde{\eta}=\eta\varepsilon_L(1-\theta_L)^{-1}[\theta_L\tilde{\varepsilon}_L-\tilde{w}-(\alpha_R/\alpha_L)\tilde{t}_R] \tag{19′}$$

where we have used $(1-\theta_L)\delta_R=\alpha_R/\alpha_L$ and where the labour tax rate is defined by $\theta_L\equiv t_L/(w+t_L)$. Substituting (8″) and (18″) into (19′), we find how the MCPF varies:

$$\tilde{\eta}=-\eta\varepsilon_L(1-\theta_2)^{-1}[(1-\alpha_V)^{-1}\beta_L^{-1}\tilde{M}+(\alpha_R/\alpha_L)\theta_R\tilde{U}_E] \tag{19″}$$

(a) Positive wage elasticity of labour supply (b) Negative wage elasticity of labour supply




*Key*: Higher $U_E$ corresponds to shift from $E$ to $E'$.

*Fig. 1.* Effects of greener preferences on private utility and the MCPF.

where we have assumed that labour supply exhibits a constant (uncompensated) wage elasticity ($\tilde{\varepsilon}_L = 0$).[8] Expression (19″) reveals how the MCPF varies with the level of private utility. We can graph this relationship as the "cost" curve in Figure 1. If the uncompensated wage elasticity of labour supply is positive (negative), the cost curve slopes downwards (upwards). Intuitively, a positive (negative) wage elasticity implies that a high level of (distortionary) labour taxation raises (reduces) the MCPF by eroding (widening) the base of the distortionary labour tax (see expression (19)). At a given resource tax, a higher level of private utility requires a higher consumption wage (see (8″)) and thus a lower distortionary tax (see, e.g., expression (7″)), thereby reducing (raising) the MCPF. Given the level of private utility (and thus the wage level), a higher resource tax, corresponding to a higher priority to the environment, allows for a lower distortionary (labour) tax rate (see (7″)). The MCPF thus declines (rises) and the cost curve shifts downwards (upwards).

*Solution*

The solution for the changes in private utility and the marginal cost of public funds corresponds to the intersection of demand curve, (24), and the cost curve, (19″), i.e., point E in Figure 1. Subsequently, (8″) can be used to find the changes in the consumption wage, private consumption, leisure and employment, (22) to arrive at the change in public consumption, and (23) to find the change in environmental quality. Solving (24) and (19″), we find:

$$\tilde{\eta} = -\Delta^{**}(\varepsilon_L \alpha_R / \alpha_L)\theta_R \tilde{U}_E \tag{25}$$

$$[\beta_L(1-\alpha_V)]^{-1}\tilde{M} = \tilde{w} = -\Delta^{**}(\alpha_L \alpha_V)^{-1}\varepsilon_L \alpha_R \theta_R \tilde{U}_E \tag{26}$$

where we assume $\Delta^{**} \equiv [1-\theta_L(1+\varepsilon_L)+\varepsilon_L/\alpha_V]^{-1} = [(1-\theta_L)\eta^{-1} + \varepsilon_L/\alpha_V]^{-1} > 0$.[9]

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[8] This implies that the elasticity $\sigma_M$ is not constant but changes so as to keep $\varepsilon_L$ constant. For a similar approach, see Wildasin (1992). Bovenberg and van der Ploeg (1992) adopt an alternative approach by assuming that $\sigma_M$ is constant. In that case, $\varepsilon_L$ varies (e.g. $\tilde{\varepsilon}_L = \tilde{V}$ if non-labour household income is zero or fully taxed away, i.e., $\beta_L = 1$). Empirical studies do not provide much guidance on how labour supply elasticities change with the level of labour supply. Furthermore, we expect these changes in elasticities to be only of minor importance — especially if the initial tax rate of labour ($\theta_L$) is small.

[9] This is the case if $\sigma_M > \beta_L \theta_L$. This condition is met if $\theta_L$ and $\beta_L$ are small or if the wage elasticity of labour supply is positive (i.e., $\sigma_M > \beta_L$). In case $\Delta^{**} < 0$, the cost curve slopes upwards and is steeper than the demand curve. The model is then unstable; a higher level of private welfare raises the MCPF, thereby making private consumption more attractive and thus raising the MCPF further. Samuelson's correspondence principle suggests that we must assume $\Delta^{**} > 0$.

## V. Increased Concern for Environmental Quality

Next, we examine the effects of a shift towards more concern for environmental quality (i.e., higher $U_E$). An alternative interpretation is that awareness of environmental damages associated with the use of resources has increased. After exploring how changes in optimal environmental and tax policies affect employment, we discuss capital flight and then investigate the consequences for private and public utility, respectively.

*Environmental Policy and Employment*

Greener preferences imply a more ambitious environmental policy at the optimum; the tax on the use of natural resources rises (see (18″)) and the level of abatement expands (see (15″)). Hence, the government should adopt a mix of environmental policy instruments.

The impact on the rate of labour taxation ($\theta_L = t_L/(w+t_L)$) is found from

$$\tilde{\theta}_L = (1-\theta_L)[(1-\theta_L)\theta_L^{-1}\tilde{t}_L - \tilde{w}]. \tag{27}$$

Eliminating $\tilde{t}_L$ from (7″), using (18″) and substituting (26) for $\tilde{w}$, we arrive at:

$$\tilde{\theta}_L = -(1-\theta_L)^2(\eta\theta_L\alpha_L)^{-1}\alpha_R\Delta^{**}\tilde{U}_E. \tag{28}$$

Hence, a rise in environmental concern reduces the labour tax rate as non-distortionary environmental taxes replace (distortionary) labour taxes.

Substituting (26) and (8″), we find that, despite the lower labour tax rate, employment declines as preferences become greener (higher $U_E$), irrespective of the value of the uncompensated wage elasticity of labour supply:

$$\tilde{L} = -\Delta^{**}(\alpha_L\alpha_V)^{-1}\varepsilon_L^2\alpha_R\theta_R\tilde{U}_E. \tag{29}$$

Only if labour supply is completely inelastic (i.e., $\varepsilon_L = 0$) is employment unaffected. In all other cases, an increase in environmental concern harms employment. Intuitively, the higher tax on resources is shifted onto the only internationally immobile factor (i.e., labour). An alternative interpretation of the decline in employment is that a relocation from the consumption of produced goods to that of leisure indirectly benefits the environment. In particular, the consumption of leisure does not pollute the environment. Employment, in contrast harms the environment because it expands the demand for natural resources (see expressions (6″) and (12″)). Accordingly, the use of natural resources falls for two reasons if environmental concern rises. First, the level of employment and thus output declines (i.e., the output effect). Second, given the level of output, the higher pollution tax encourages firms to substitute away from natural resources (i.e., the substitution effect). The environment thus benefits from both a lower *level* and a cleaner *composition* (i.e., less resource intensive production and more public abatement) of activity.

*International Capital Flows*

We use (6) to arrive at an expression for the change in domestically employed capital:

$$\tilde{K} = \tilde{L} - \varepsilon_{KR}\tilde{t}_R \tag{30}$$

where $\varepsilon_{KR} \equiv F_{RK}(P_R^* + t_R)/k\Delta^*$ is positive (negative) if capital and natural resources are (non)cooperant production factors. Just as in the case of resource demand, an output and a substitution effect determine the impact on the domestic demand for capital. First, greener preferences reduce employment and output, thereby depressing the demand for capital. Second, firms change their input mix in response to the higher user price for resources and lower labour costs. In particular, if resources and capital are (non)cooperant production factors, firms substitute away from (towards) capital. Hence, a greater concern for the environment typically induces capital flight. The only exception is if labour supply is inelastic ($\varepsilon_L$ is small in absolute value, i.e. $\sigma_M \approx \beta_L$). Moreover, resources and capital should be noncooperant factors of production. This is the case if resources and capital are weakly separable from labour in production and, at the same time, resources and capital are close substitutes while the compositie of resources and capital is a poor substitute for labour. In that case, firms substitute capital rather than labour for resources if they face a higher cost of resource use and lower labour costs. In particular, the condition for capital demand to rise if labour supply is inelastic is $\sigma_K > \sigma_L/\alpha_L^*$, where $\sigma_K$ is the substitution elasticity between resources and capital, $\sigma_L$ denotes the corresponding elasticity between labour and the resource-capital composite, and $\alpha_L^* \equiv (w + t_L)NL/F(K, NL, R)$ stands for the labour share in production. Accordingly, in contrast to the demand for labour and resources, capital demand may rise if particular production conditions hold. In most cases, however, the demands for all three inputs into production decline. Furthermore, production typically becomes more labour and less resource intensive as wage costs fall and the cost of using resources rises.

Greener preferences reduce the import of natural resources and, typically, encourage capital flight. It thus follows that the trade balance for exports and imports of goods moves into deficit. Intuitively, a more ambitious environmental policy makes domestic production less attractive so that a larger share of domestic endowments of capital and natural resources is employed abroad. The (factor) income from abroad is used to import consumption goods.

*Private Utility*

The impact on private utility depends on the sign of the uncompensated wage elasticity of labour supply, $\varepsilon_L$. If this elasticity is positive (negative), greener preferences reduce (raise) private utility. Intuitively, the higher environmental tax allows for a lower distortionary tax on labour. According to expression (19), this reduces (raises) the MCPF if the labour supply slopes upwards (downwards). A lower (higher) MCPF expands the public sector (private utility) at the expense of private utility (the public sector) (see expression (24)). Graphically, greener policies shift down (up) the downward- (upward-)sloping cost curve if the elasticity $\varepsilon_L$ is positive (negative).

*Public Consumption*

Public consumption is found by substituting (26) into (22):

$$\omega_G \tilde{G} = [(\Delta^{**}/\alpha_V)\Delta^* \varepsilon_L(\alpha_R/\alpha_L) - \theta_R \alpha_R \varepsilon_R]\theta_R \tilde{U}_E - \omega_A \sigma_A^{-1} \theta_R \tilde{U}_E. \tag{31}$$

Public consumption rises with environmental concern if the labour supply elasticity is positive and large and, at the same time, $\varepsilon_R$ and $\sigma_A^{-1}$ are small. Red preferences (i.e., concern with public consumption) and green preferences (i.e., concern with environmental quality) are then compatible in the sense that an increase in environmental concern expands public consumption. The conditions for the compatibility of red and green preferences can be explained as follows. With upward-sloping labour supply, the higher non-distortionary resource tax cuts the MCPF. This reduces the demand for private utility (see expression (24) and Figure 1 where the cost curve shifts down). The associated lower consumption wage allows for higher overall rates of taxation (consisting of both the explicit labour tax and the resource tax, which is an implicit labour tax, see expression (7″)). With a small $\varepsilon_R$, the change in the tax composition away from (explicit) labour taxation toward environmental taxation, does not erode the base of the resource tax much. The resource tax is thus almost as effective in raising revenues as the explicit labour tax. Hence, the rise in the overal tax rate causes revenues to expand, thereby boosting overall public spending. This allows public consumption to rise because, with a small $\sigma_A^{-1}$, public abatement increases only marginally (see expression (15″)).

Public consumption can increase only if the environment improves mainly through a lower level of economic activity rather than a cleaner composition of that activity. In particular, with a large uncompensated wage elasticity, employment and hence output decline substantially (see (29)). If $\sigma_A^{-1}$ is small, public abatement does not expand much (see (15″)). Furthermore, production does not become much less resource intensive if the elasticity $\varepsilon_R$ is small (see expression (6‴)). Hence, environmental quality is not enhanced by a cleaner composition of economic activity but rather by a lower level of that activity (see also (12″)).

If either $\sigma_A^{-1}$ or $\varepsilon_R$ are large, public consumption declines. In that case, a "greener" composition of economic activity contributes to a higher environmental quality. In particular, if $\sigma_A^{-1}$ is large, public abatement rises substantially. This both enhances environmental quality and crowds out public consumption. If the elasticity $\varepsilon_R$ is large, production becomes much less resource intensive, thereby benefiting the environment. At the same time, however, the base of the resource tax erodes causing aggregate revenues to fall. This drop in revenues forces the government to cut public consumption. Intuitively, by cutting public spending, the government creates room for the private sector to incur the costs associated with a cleaner production structure. In case of a large $\sigma_A^{-1}$, the costs associated with a higher social priority for the public good of a cleaner environment appear explicitly on the government budget as a higher level of public spending on abatement. In case $\varepsilon_R$ is large, in contrast, the costs incurred for a higher environmental quality are "hidden" in the form of a larger excess burden per additional unit of public revenue raised.

If the natural resources are fossil fuels, public abatement possibilities may be limited. The costs associated with a cleaner composition of economic activity then do not appear on the government budget. Hence, the government may have to return to the private sector *more* than the additional revenues from pollution taxes, especially if $\varepsilon_R$ is large and $\sigma_M$ is small.

## VI. Extension: Environmental Quality and Production

If environmental quality benefits productivity as well as utility, we have:

$$Q_P = a(E)F(K, NL, R), \quad a' > 0, \quad a'' < 0, \tag{32}$$

where $Q_P$ denotes domestic output of goods. For example, in agriculture, production benefits from a better quality of the soil and the air. A cleaner environment also reduces congestion and smog, thereby improving health and morale and thus boosting productivity. According to (32), environmental quality enhances the productivity of all inputs. An alternative would be that environmental quality affects labour rather than general productivity.

The demands by firms for capital and natural resources relative to employment, (6), are unaffected. However, the factor price frontier becomes

$$w + t_L = \phi(P_K^*, P_R^* + t_R, E) \tag{7‴}$$

with $\phi_K = -k$, $\phi_R = -r$ and $\phi_E = [a'(E)F(K,NL,R)/NL] > 0$. A better environmental quality boosts the marginal productivity of labour and thus the wage. The expression for the optimal tax rate on resources becomes:

$$t_R = (NU_E/U_M M_C)\eta^{-1} + a'(E)F(K, NL, R). \tag{18'''}$$

The expressions for the optimal provision of public goods, (14), the optimal level of public abatement, (15), and the MCPF, (19), are unaffected.

The main difference from the case in which environmental quality benefits only utility is that, in addition to a term to correct for the consumption externality (cf. Section III), the tax on renewable resources incorporates a term to take into account the adverse impact of resource use on productivity. In contrast to the first term for the consumption externality, the second term corresponding to the production effect does not involve the MCPF. This may have important implications. If public funds become scarcer, the government's ability to differentiate tax rates for environmental purposes is not necessarily affected and thus the tax on resources need not fall. Moreover, employment may rise rather than fall as a cleaner environment boosts labour productivity and thus wages.

## VII. Conclusions

This paper explored the implications of greater environmental concern for optimal policy and various macroeconomic variables in the context of a second-best, small open economy with environmental externalities in production. We found that increased concern for the environment reduces employment despite the factor substitution induced by a lower tax on labour and a higher tax on natural resources. This result is independent of the sign of the uncompensated wage elasticity of labour supply.

The "pessimist" view on environmental policy maintains that a cleaner environment requires a lower level of economic activity. Indeed, with a large uncompensated wage elasticity of labour supply, employment and output may drop substantially in response to greener preferences. The reason is that the higher environmental tax that is associated with greener preferences is shifted towards labour. With elastic labour supply, the resulting lower wage rate exerts a large adverse effect on labour supply. If the marginal productivity of public abatement falls rapidly with the level of abatement and if the input mix into production is not very sensitive to the user price of resources, most of the improvement in environmental quality is achieved through a lower level of economic activity rather than a cleaner composition of that activity, thereby providing support to the pessimist view. Under these conditions, red and green preferences are compatible, i.e., public consumption rises with more concern for the environment.

Intuitively, if the environment is improved through a lower level of output, the disincentive effects of financing public consumption are less damaging. The pessimist scenario is consistent with not only a lower level of employment but also capital flight.

The alternative "optimist" view argues that a high environmental quality can be reconciled to a high level of output because it can be achieved through a cleaner composition of economic activity. If this is the case, optimal public consumption falls with more environmental concern. Whereas employment does not rise, the demand for capital may expand if resources are a close substitute for capital but not for labour.

Hansson and Stuart (1993) use aggregate time series data to estimate uncompensated wage elasticities of labour supply, ranging from about a half for the UK, the US, Canada, and Australia to more than one for Belgium, the Netherlands, Denmark, Norway, and Sweden — rather higher than the traditional cross-section estimates. These empirical results imply that employment may have to drop substantially in response to greener preferences. In the short run, output effects dominate substitution effects in production. Hence, most of the improvement in environmental quality must come from a fall in economic activity. At the same time, public consumption may expand as the environmental taxes yield substantial revenues and the marginal cost of public funds declines. In the long run, more substitution of clean for dirty factors of production is feasible. Hence, public consumption may decline as revenues from dirt taxes drop off.

In future work we plan to investigate in more detail the consequences of a beneficial impact of environmental quality on productivity. Moreover, we want to analyse optimal environmental and tax policies in economies with involuntary unemployment and heterogeneous agents.

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